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## SOME REMARKS ON THE MANUFACTURE OF BAR IRON IN NORTHERN NEW YORK. *By* W. R. CASEY, *Civil Engineer.*

The manufacture of iron is a subject to which, judging from English journals, the Civil Engineers of that country pay much attention, and as its use is rapidly on the increase here, and as its importance in a national point of view is continually alluded to in the public prints, the writer has been induced to offer the following remarks, which may perhaps interest some of the profession whose acquaintance with the manufacture of this metal is as slight as his own was till lately; by which, however, he means to intimate no more than that his present knowledge of the subject is still exceedingly limited.

The ordinary mode of making wrought iron in England and Pennsylvania is generally known, but, as this requires immense quantities of coal and as none is found in this State, and as the ore here is entirely different, the mode of producing iron directly from the ore patented in England, by Mr. William N. Clay, by which a very small quantity of coal or charcoal is required with *such* ore, becomes of almost vital importance to northern New York; for, though the forests might last for ages, the expense of transporting coal to the works would necessarily limit the manufacture, when as now 300 bushels of charcoal per ton are required, while, by Mr. Clay's plan, 5 bushels would be sufficient for the first process, dry wood answering for the remaining operations,—the entire quan-

tity of fuel being less than one-fourth of that required by the present mode, with a greater yield of iron from the same quantity of ore as well as a better quantity. The following extracts are from the remarks by the patentee, in the Civil Engineer and Architect's Journal, 1839, page 17.

"Iron is popularly divided into two descriptions, cast and wrought.

"Cast or pig iron, is principally a combination of the metal with carbon, which it absorbs from the coke or charcoal of the blast furnace. Wrought iron has been hitherto produced by freeing cast iron from the carbon, etc., with which it is combined: the nearer it approaches to a state of purity, the better wrought or malleable iron will it be.

"The richer ores of iron contain the metal combined with oxigen; if that oxigen were separated, the metal would be in its malleable state as wrought iron.

"And yet, the advance of science has left this great branch of our national prosperity so far behind, as to suffer the manufacturer still to continue the practice of impregnating the iron with carbon in the first instance, which carbon must afterwards be separated, by tedious and expensive processes, to produce wrought iron of good quality.

"But there are other evils in the common mode. It is necessary for the manufacturer to have a sort of glass floating on the molten iron at the bottom of his furnace, to prevent the oxidation of the recently produced metal by the blast. This glass is formed from the earths with which the ores of iron are mixed, and limestone to flux those earths: so that, ores of a very superior quality cannot be used by themselves, but only in part, to enrich such poor ores as have more earths combined with them than are necessary for their own fusion. Thus it is that the Hematites, and other rich ores, found abundantly in Lancashire, Cumberland, Cornwall, etc., reach no higher a marketable value at the place of their production than the common earthy ores of the coal districts, although they contain twice as much iron, and that iron of a very superior quality.

"It is the object of the patent taken out by Mr. William Clay, to produce wrought iron of best quality, direct from the rich ores heretofore so little used from the causes before named, by a process simple, rapid and economical.

"To make wrought iron of such quality, for instance, as chain cables are made from, five several operations are necessary, besides the preliminary one of making the coke for the blast furnace, namely—

"1. Roasting the ore.

"2. Smelting in the blast furnace.

"3. Refining.

"4. Puddling, balling, hammering and rolling.

"5. Cutting up, piling, and rolling.

"All these processes requiring a separate application of heat.

"It is stated in the article on iron, the 106th number of the 'Library of Useful Knowledge,' a work written with great clearness, and an intimate knowledge of the subject, that 8 tons 17 cwt. 3qrs. 3lbs. of coals are required for the production of 1 ton of finished bar iron; doubtless, the introduction of the hot blast has reduced the consumption of fuel in the smelting operation considerably, and the adoption of anthracite coal may decrease it still further. It seems, however, yet doubtful, whether the best bar iron can be produced from 'hot blast pig:' at all events, very small proportions of that description are as yet used in the fabrication of iron of superior quality.

"On the patent plan the operations are reduced to three; namely—

"1. Reducing, or preparing the ore in retorts, or other close vessels.

"2. Balling hammering and rolling.

"3. Cutting, piling and rolling.

"The first of these processes is accomplished by the otherwise waste heat of the two latter, so that only two separate applications of heat are required; and the second operation on this plan commences with the iron in as forward a state as the fourth of the old mode, whereby the cost of fuel and labor, and the enormous outlay of capital in land, blast furnaces and machinery required to bring iron on the old mode to the third stage, are all avoided.

"It is now necessary to state how this is to be accomplished.

"Refering to the plan, it will be seen that between a reverberatory furnace of the common construction employed in 'puddling,' 'balling,' or 'piling' iron, and the chimney, a range of retorts are placed, which are heated on their exterior by the otherwise waste heat of the furnace.

"Into these retorts are thrown 100 parts of Ulverstone, or other rich ore, and 20 parts of coke dust, ground charcoal, anthracite or other carbonaceous matter, well mixed together. The retort is closed, and the vapors generated escape as gas. In the course of from 30 to 48 hours, as the heat is greater or less, the carbon will carry off the oxigen, and leave the iron in a metallic state.

"It has then to be taken to the balling furnace, where it welds up, like scrap iron, and in 15 minutes is ready for the hammer; thence it undergoes the customary process of rolling.

"It is then cut up, piled, and rolled, and the operation terminates, with the production of bar iron of superior and extraordinary quality.

"The fourth operation of the old process, 'puddling,' takes from 1½ to 2 hours to perform; the second operation of the patent, only 15 minutes; consequently, the consumption of fuel will be much less than if refined iron were used. It would be idle to compare the simplicity and economy of the first stage of the patent process, with the cost of the three stages required to make the iron stone into refined iron on the old mode, when we find by referring to page 28 of the work alluded to, that of the 8.889 tons of coal consumed in the whole process, 6.989 tons are used up to the refining, so that the 1.9 tons required for the subsequent operations, may be calculated on as more than sufficient for the patent plan—to which may be added (if the furnaces themselves do not supply sufficient cinders,) the one-fifth part of the weight of the ore used, to mix therewith, as carbonaceous matter.

"It now remains to notice the quality of the iron. In no one respect is it inferior to 'best common,' and in many of its properties it is equal to Swedish or charcoal iron; its tenacity is so great, that of four trials made with patent iron (1 inch chain,) at the corporation testing machine, Liverpool, not one broke with a less strain than 26 tons, and one link required 28 tons 12½ cwt. to break it, the standard test for that size being 16 tons.

"Experiment on Mr. Clay's method of making bar iron,—150 lbs. of Uverstone ore and 40¼ lbs. of wet coke (losing 12½ per cent. in drying) were put into one of the gas retorts in Dale street, on Saturday, November 24, at five in the morning, and remained in till ten on Tuesday evening, or 65 hours. The heat was maintained at a full red, or common gas-making heat. The above quantity reduced at the Mersey forge (two miles distant) produced in 34 minutes two balls of iron—one of 32 lbs., and one of 26 lbs.—58 lbs. The former rolled to 1¼ inch puddled bar, weighed 30 lbs., and was then brought down under the tilt to ¾ inch square, and samples taken when broken. The yield 38⅔ per cent."

The mode in use in northern New York is, with the exception of the hot blast, the very same as that practised in England several centuries since as decribed in the Cabinet Cyclopœdia The ore, which is nearly pure oxide of iron, is taken from the mine to the forge without any preparation (from the best mines) and is sprinkled

on the burning charcoal through which it passes, and being *very nearly* in a state of fusion, the particles adhere to each other; when a sufficient quantity is collected it is taken out and put under a trip hammer to drive out the cinder and consolidate the mass. Before hammering it is called a "loop," afterwards a "bloom." It is then hammered or rolled into bars, etc. Now, it will be easily seen, that if the loop be too much heated, carbon will be absorbed and cast iron will be the result, so that when put under the hammer it flies in every direction, hence great skill is required in the "bloomer" to know the exact time of taking out the loop. But, even with every precaution, it appears to the writer that a considerable portion of the loop must be consumed, for, as the ore passes through the charcoal, the latter absorbs the oxigen, pure iron then remains, which, it is well known, burns rapidly away, and as the loop is for some time exposed to a great heat, he thinks this will in part, at least, account for the great consumption of this rich ore—2 to 2½ tons per ton of bars. The uncertainty as to the quantities of coal and ore required to produce a ton of iron is proof of some varying cause of loss, but whether the above explanation be sufficient or not it is for better judges to say.

As steel is composed of pure iron and a two or three hundredth part of carbon, it will be seen, that by exposing the loop to the charcoal a little after it is in the best state for malleable iron, but not long enough to unite with sufficient carbon to become cast iron, a kind of steel would be produced, and this has repeatedly happened, though only a single instance is known to the writer of such steel having been actually *used*. Cast iron, malleable iron and steel were made from the same ore at Adirondack, in Essex county, and a mechanic, now in this city, used an accidental bar of steel for cold chisels, pronouncing it equal to the best English. Whether there is any probability of uniformly producing such steel in the forge is a question of interest and perhaps difficulty,—certainly to the writer, who is unable to offer any opinion on it. Professor Emmons, the State Geologist, considers it practicable.

Castings made from the so called "steel ore," found at Duane, in Franklin county, have the property of tempering and take a fine edge. Some time since, this steel was tried at the works of the Peru iron company, but after cutting a few nails the edges chipped off, it appeared sufficiently hard, but having no fibre was necessarily deficient in tenacity and strength.

This kind of cast iron is well known in England, where it is run into knives, scissors and other articles of cheap cutlery; these are

then rendered malleable, by a process well known in this country, finished and hardened. An inquiry into this subject of any experienced and respectable importer of hard-ware, would have saved the State Commissioners and other functionaries the mortification of announcing, as a grand discovery, a physical impossibility,—these castings were to possess *all* the properties of the best cast steel! Where would the fiber strength, elasticity and malleability of steel come from?

Trials on a small scale have been made by Mr. Clay's process, and pieces containing half a cubic inch, after being subjected 36 hours to the action of charcoal at a red heat only, have been then heated to a welding heat in a blacksmith's fire and drawn out into excellent iron. Such small fragments of ore, after parting with their oxigen, may be considered as scrap iron, and formed into bars in the same manner, by heating them in a "balling" or "puddling" furnace to a welding heat and then drawing them out under the hammer.

If the ore be exposed too long to the action of the charcoal, more especially at a high temperature, it will, after losing its oxigen, combine with carbon and pass through the different stages of steel and the various grades of cast iron to the carburet. Of course nothing but experience can enable us to say what time and heat are required to completely de-oxidize the ore, when it should be immediately taken out of the charcoal, being then in a state of pure iron, except a very small portion of earthy matter which is driven out by the hammer. Hence the purer the ore the better by this mode, while by the ordinary mode, rich ores cannot be worked as explained by Mr. Clay. It would appear possible by this process to produce steel directly from the ore, but whether it would be uniformly equal to steel made by the ordinary process of "cementation," where bars of the best manufactured iron are subjected to the action of heated charcoal for a long time, it is useless to conjecture, as numerous successful trials on a large scale can alone decide it satisfactorily. In the meantime, the fact that excellent steel has been made and actually used for cold chisels, and the, as far as the writer is able to judge, clearness and simplicity of Mr. Clay's theory and process would appear sufficient to warrant some well conducted experiments.

The bloomers are paid by the ton as in England, but are not, as there, obliged to account for the ore and coal consumed; hence, if by neglect or ignorance, they use 50 bushels of charcoal to destroy 2 or 300 weight of ore, the loss falls on the proprietor. In-

deed, with the common forge, it would appear impossible to attain anything like regularity in the yield of iron to the ore and coal consumed, as the entire process is carried on in the dark, and everything depends on the skill of the bloomer, whose only object is to turn out the greatest quantity of iron in a given *time* without reference to the *coal* and *ore* used, in which the employer is only interested. The writer was often led to observe that the English term for the latter "iron-master" was, in northern New York, much more applicable to the former. Now, Mr. Clay's mode, by divesting the manufacture from all mystery, by rendering the greatest possible yield almost certain, by improving the quality, by immensely reducing the consumption of fuel and by simplifying the manipulations must place the counties of Clinton and Essex among the most productive in the State; for the quantity of ore is inexhaustible, and the quality at least equal to any yet known in this country. Should the process of making iron from the rich, almost pure ores found in the primitive rocks only, succeed as well as the inventor anticipates, no coal region can compete with these counties in the manufacture of fine bar iron, boiler plates, chain cables, etc., for these would be produced of the best iron in northern New York as cheaply as of the common iron made from the course ores of the coal districts of Pennsylvania; though the latter would furnish pig iron for ordinary purposes more cheaply than the former. Pennsylvania has also the advantage of having coal and ore distributed over an immense extent of country;—on the other hand, the *very* rich ores of northern New York are confined to few localities. These circumstances would indicate that the former State is adapted to the production of an unlimited quantity of cheap iron, of which the consumption is immense; the latter State to the production of the best qualities of bar iron and steel, which are of great value, though the consumption is comparatively small in quantity. The present state and extent of the trade will be given in a future number.

NEW YORK, *April*, 1842.

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[For the American Railroad Journal and Mechanics' Magazine.]

## BALTIMORE AND PHILADELPHIA RAILROAD AND RIVER LINES.

### REPORT FOR 1841.

In these times of general depression or rather of total wreck, it may be as well to record the actual condition of the main lines, and to show to what it is owing that they are in part or in whole failures. The railway portion of this line, particularly between Phil-

adelphia and Wilmington, was completed in a very great hurry, and therefore has had its annual outlay for repairs much increased, and it is only now in the fourth year after the opening of the entire line, that the road and its superstructures have attained a substantial character, and which with very slight exceptions in regard to some of the smaller bridges, will be the means of much saving hereafter.

| | | | |
|---|---|---|---|
| The 95 miles of railway with depots, motive power and all appliances cost, - - - - | | | $4,588,300 |
| The river route, including 16 miles railway, between Frenchtown and New Castle, and steamboats, etc., | | | 727,600 |
| | | | $5,315,900 |
| The capital stock is, - - | | $2,818,300 | |
| The loans are, at current dates, | $189,700 | | |
| " " Due June 1, 1842, | 700,000 | | |
| " " " April 1, 1842–'43, sterling bonds, | 502,200 | | |
| " " " In all, 1843, to State of Delaware, | 80,800 | | |
| " " " February 1, 1844, | 798,800 | | |
| " " " November 1, 1850, sterling bonds, | 226,100 | | |
| | | $2,497,600 | |
| | | | $5,315,900 |
| The receipts in 1841 for travel were on 234,739 way and through travel, or 94,725 through travel, $4, | | | $378,900 |
| Freight by railroad, - - - - | | | 44,800 |
| Mail, - - - - - - | | | 30,600 |
| Toll and rents, - - - - - | | | 7,700 |
| Travel and freight on river route, - - - | | | 142,000 |
| | | | 604,000 |
| Expenses on both lines, which is stated to include much new work, more properly belonging to construction account, - - - - - - | | | 308,000 |
| | | | 296,000 |
| Deduct interest on loans, - - | | $150,000 | |
| Dividend in August, 1841, 3 per cent. (the last,) | | 85,000 | |
| | | | 235,000 |
| Applied to liquidate current loans, - - - | | | $61,000 |

| | |
|---|---|
| The average repairs of road and maintenance, etc., for the last three years, have been, on the Philadelphia and Havre de Grace division, 60 miles, - - | $500 per mile per an. |
| Havre de Grace and Baltimore division, 33 miles, - - - - | $458 " " |

The latter division includes their long bridges, and is a moderate charge compared with the apprehensions at first entertained, and the whole line of road is now reported in thorough repair.

This enterprise has had every disadvantage to contend against,—obliged to use horse power at *either end* and a steamboat in the middle,—with two sets of machinery, the expenses have necessarily been very heavy, besides the delays and inefficiency occasioned by a want of continuity in the line,—the feature above all others of *most value* in these costly enterprises, and yet which is found to obtain so little or rather not all on any of the great avenues. The river line is entirely superfluous, and is only so much dead weight. It is to be regretted that their charter compels them to run both lines. To add to all this, the bulk of the loans have been at short dates, falling due in the very crisis of the monetary difficulties of the country, and is the main contributing cause to the stock now selling at $10 for $50 paid.

The business on the road has been at a steady rate of 8 to 10 per cent. increase per annum, and an important accession to it will be found in the completion of the Baltimore and Ohio railroad to Cumberland, expected in the fall of 1842.

It is stated that much economy has lately been introduced in the management of this line, and it now only remains for them to have their loans put on a proper footing, to re-establish the value of the stock, which cannot fail to yield 6 per cent. per annum on the par value of $50 per share.

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[For the American Railroad Journal and Mechanics' Magazine.]

### CAMDEN AND AMBOY RAILROAD AND DELAWARE AND RARITAN CANAL.—TRANSPORTATION COMPANIES.

The first report of these joint companies was made in January, 1840, and a second has recently appeared giving a statement in continuation of their operations down to December 31, 1841.

| | |
|---|---|
| The length of road with branches and turnouts is 98¼ miles, costing, equipped as per report, - - - | $3,220,000 |
| The length of canal is 43 and feeder 22 miles, costing, equipped as per report, - - - - - | 2,830,000 |
| | 6,050,000 |
| In June, 1836, the Trenton and Philadelphia railroad, 30 miles, was added to this concern, to share equally in all dividends, at a cost said to be about, - - | 999,600 |
| | $7,049,600 |

The annual interest on the loans as part of the above cost is stated to be $189,600, and which are payable at long dates. The railway got into full operation between New York and Philadelphia in the year 1833, and the following statement will show the progress of business since that period on it and the canal:

| Year. | Passengers. | Freight in tons. | Gross receipts. | Expenses. | Nett receipts. |
|---|---|---|---|---|---|
| 1833, | 109,908 | 6,043 | $468,142 | $287,091 | $181,050 |
| 1834, | 105,418 | 8,397 | 546,993 | 313,261 | 233,731 |
| 1835, | 147,424 | 10,811 | 679,463 | 317,491 | 361;971 |
| 1836, | 163,731 | 12,508 | 770,621 | 363,344 | 407,276 |
| 1837, | 145,461 | 10,642 | 731,995 | 359,510 | 372,484 |
| 1838, | 164,520 | 11,765 | 754,989 | 355,249 | 399,740 |
| 1839, | 181,479 | 13,520 | 685,329 | 258,043 | 427,286 |
| 1840, | 162,690 | 11,207 | 645,008 | 285,406 | 359,602 |
| 1841, | 162,810 | 14,579 | 760,255 | 355,538 | 404,716 |
| | 1,343,441 | 99,472 | $6,042,795 | $2,894,933 | $3,147,856 |

The canal appears to have commenced operations in 1834, and its receipts and expeditures are given as follows:

| | Tolls. | Expenditures. |
|---|---|---|
| 1834, - - | $11,604 | |
| 1825, - - | 47,141 | $49,243 |
| 1836, - - | 54,801 | 34,764 |
| 1837, - - | 67,194 | 27,079 |
| 1838, - - | 73,507 | 46,007 |
| 1839, - - | 52,643 | 53,248 |
| 1840, - - | 79,467 | 40,769 |
| 1841, - - | 81,543 | 49,509 |
| | $467,900 | $300,619 |

In the above expenditures on the railway is included the transit duty to the State of New Jersey, equal now to about $25,000 per annum; deducting this, the ratio of expenses for the last two years is about 40 to 42 per cent. on the gross receipts, but under a different arrangement, might be reduced 10 per cent., considering the magnitude of the receipts.

The canal has always been, and the Trenton railway has lately become, a drag on this concern, yet with all this burden it still yields an income on the whole cost, and *by itself as a railway*, is one of the most profitable concerns in the country. The canal has now, however, the prospect of getting the whole coal trade, and the Trenton railroad will, we trust, be ere long relaid with an edge rail, and its termination carried into Broad street, at Philadelphia, where all the other railways now concentrate. If, as the result of this, the traveller is carried between these two important cities in four and a-half to five hours, by which the day will be made available to him in either, fresh inducement will be given to travel, even though the fare be kept at the high rate of $4 per head, which would then be the more cheerfully paid, and is even now preferred as the cheapest by a majority, as appears by the returns of 1841, when

90,000 passengers passed over the Jersey railway, through Brunswick, at $4.

72,800 passengers passed over the Camden and Amboy railway, at $3.

162,800 through passengers by both lines.

The charges for freight between New York and Phildelphia, on the Camden and Amboy line, are complained of as too high, and naturally enough, when at the adjoining wharf goods are carried to Boston by a similar mixed conveyance $5 to $7 per ton, for 230 miles, and are here charged for little over one-third of that distance $15 to $20 per ton; the same contrast applies between other points in even a stronger degree. Quantities of goods, such as hemp, rattans, etc., are often sent by sea at $8 per ton including insurance, when $10 has been offered in vain to this railway. Its charter does not allow of a higher charge than $8 per ton, and the 14,600 tons carried in 1841 are credited to it at about $9, while the average charge cannot be much less than $16; the difference being charged by the "*Union Transportation company*" for the distance by steamboat of 30 miles to Amboy. It is strange enough, however, that the board of directors of the railway approve of this system in the following terms:

"The great and growing importance and value of this business has deeply occupied the most serious attention of the board, to ascertain to the greatest certainty the most advantageous and profitable mode of conducting it. They believe that in no other way than the one in which it has been conducted for some years past, by the intervention of other parties, could so large a revenue have accrued to the companies. By the existing arrangement with the New Brunswick steamboat and canal transportation company, this whole business is done by them. The joint companies avoid all liabilities for losses or damages to property passing over this road or in their boats between New York and Philadelphia, and at a less cost than a commission of 5 per cent. on the business would amount to."

Still it is not so clear to our apprehension, that this system of "*imperium in imperio*" can answer any better in the management of the railway, than it has been found to do in the government of a State. A nearly similar system, as regards the "*forwarding men*," on the Columbia railway, has lately been condemned by the Canal Commissioners of Pennsylvania.

The charges by the canal route, by the same *sub-company*, are more moderate and consistent, but might still be modified so as to get much more of the freight now sent coastwise,—lower rates by the railway would command it nearly all.

The measures proposed by this company for securing the coal trade through the Delaware and Raritan canal are judicious, and are explained in the following extract:

"Experience has demonstrated to general satisfaction, that the cheapest, safest and most expeditious route to New York is by the Delaware and Raritan canal, and the completion of the Reading railroad will add still greater facilities for the transportation of coal through it. Four iron steamboats, with steam engines in each, with the capacity to carry 230 tons of coal each, are now being built by individual enterprise for the purpose of transporting coal to New York and eastward.

"It is proposed to establish depots at Amboy, etc., and to offer to vessels purchasing coal at these depots for eastern ports, a bounty in the form of payment to them of 10 cents on every ton of coal so purchased by them; and to transport such goods as they may be loaded with, destined for Philadelphia, over the Camden and Amboy railroad or by the Delaware and Raritan canal, at rates so reasonable as to ensure the business."

One of the great benefits of this coming revolution in the coal trade, as the effect of the Philadelphia and Pottsville railway, is seen in the reduction of the freight and toll between Pottsville and New York, charged at one time last year as high as $5 20 per ton, but now offered to be done for $2 50 to $2 75 per ton. A still further reduction will be effected on the introduction of the iron steam barges alluded to above, the cost of plying them between the coal wharves, on the Delaware, and New York, to and fro,—130 miles tideway, 86 miles of canal,—being about as follows:

| | | |
|---|---|---|
| Cost of iron steam barge $7,500 at 6 per cent. interest per annum, making a trip every 5 days, say 45 trips per season, is per trip, | | $10 00 |
| Renewal of steam engine, (the boat itself being nearly everlasting,) per trip, | | 6 00 |
| Engineer and firemen and victualling per trip, | | 15 00 |
| Fuel, (coal dust, at $1 per ton, may be used) per trip, | | 7 00 |
| Unloading boat, using machinery at 6 cents per ton, | | 12 00 |
| | | $50 00 |
| Two hundred tons of freight is per ton, | 25 | |
| Toll to the Delaware and Raritan canal, | 25 | |
| | | 50 |
| Cost of a ton of white ash at the mine, including profit, | $1 25 | |
| Freight per railway delivered into barge on the Delaware, | 1 50 | |
| Shipping charges, | 25 | |
| | | 3 00 |
| Cost of coal afloat in New York, | | $3 50 |

At this rate of cost, the Schuylkill white ash coal could be afforded to advantage in New York afloat at $4 per ton, or cheaper than from any other source,—and an interesting fact in regard to the economy of this fuel is given in their last report, which states that in one of their steamboats the consumption of coal was at $10 per day, as compared with $27 per day with wood.

[For the American Railroad Journal and Mechanics' Magazine.]

PHILADELPHIA AND POTTSVILLE RAILWAY.

By a report from the engineers of this company, Messrs. Moncure and Wirt Robinson, dated December, 1839, the following particulars in regard to the cost of this road are given:

88 miles of single track between Pottsville and the Columbia railway bridge, at Peter's island.

6½ miles of double track between the falls of the Schuylkill and the wharves on the Delaware, at Richmond.

| | | | |
|---|---|---|---|
| 94½ miles, or equal to 101 miles of single track, total cost, including everything, *having an edge rail, and graded for two tracks,* - - - - | | | $4,353,000 |
| Cost of locomotives and cars up to January 1, 1840, - - - - | $188,000 | | |
| Required further for the coal business, say 20 locomotives, at $7,500 each, - - | $150,000 | | |
| 1,300 cars, at $250 each, - | 325,000 | | |
| | | 475,000 | |
| | | | 663,000 |
| Equal to about $50,000 per mile of single track with machinery, - - - - - - | | | $5,016,000 |

In the above cost, the charge for right of way averages about $2,500 per mile for the whole distance.

In the history of this road, it will be of interest hereafter to know that, when almost broken down and nearly in reach of its final object, *the coal mines at Pottsville,* and when its numerous enemies were most certain of its failure, the Bostonians on the one hand, and the Baltimorians on the other, uniting with its few friends in Philadelphia, supplied the requsite means to insure its completion, while New York, the most interested in its effects, did not contribute a cent. Its opening on the 10th of January, 1842, was the overthrow of the canal monopoly in the carriage of this important staple. The great mass of the Schuylkill coal operators till now beggared, in being the sport of so many contingencies, will hereafter go on to prosper under *steady and moderate* prices, and with the blessings of many a poor man and his children, who till now could but seldom enjoy the great comfort of a warm fire.

It is common to speak of this road as a very dear one,—it is

seemingly a very costly one,—but for this *full value* has been obtained in the substantial character of all the work on it, and the facilities given to it for cheap transportation; which we confidently expect it will soon be able to demonstrate, by its annual expenditures showing a smaller per centage on its gross receipts, than we have as yet been accustomed to. Time, we believe, will show that the engineers of this road have acted on the truth of the following sentiment in a line of Pope, in matters of this sort, that,

"'Tis only usefulness that sanctifies expense."

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[For the American Railroad Journal and Mechanics' Magazine.]

## ADVANTAGES OF A CONTINUOUS RAILWAY FROM THE COAL MINES TO TIDE-WATER.

The coal trade of the Schuylkill is now destined to the following points of consumption:

| | |
|---|---|
| The city of Philadelphia and vicinity takes about, - | 100,000 |
| The city of New York and vicinity, via. the Delaware and Raritan canal in barges, - - - - | 250,000 |
| The cities of Boston, Providence and eastern and southern coast in vessels by sea, - - - - | 200,000 |
| Total tons, - - - - - | 550,000 |

There being now two avenues to tide-water in the choice of the operator, the *canal and railway*, what are the transportation and incidental charges by each respectively, and by which will the larger amount of trade be done ultimately, when the railway is made to operate with all its efficiency?

*The canal,—*

| | | | |
|---|---|---|---|
| Now charges for toll, - - - | 54 | | |
| The freight say, affording a mere living, - | 90 | | |
| | | $1 | 44 |
| Incidentals, wastage on the canal and piling a portion on the wharves, - - | 36 | | |
| Use of Pottsville landings, - - | 12 | | |
| Shipping into vessels on the Schuylkill by wheelbarrows, - - - - | 25 | | |
| Wharf rent clerk hire, etc., - - | 12 | | |
| | | 85 | |
| Amount carried over, - - - | | $2 | 29 |

| | | | |
|---|---|---|---|
| Amount brought over, - - - | | | $2 29 |
| *The railway,—* | | | |
| The toll and freight, delivered at Peter's island or on the Delaware, - - | | 1 50 | |
| Incidentals, wastage, shipping charges, wharf rent, etc., applicable to delivery on the Delaware, or to cover toll over State road into Broad street, and yard rent, etc., | | 44 | |
| | | | 1 94 |
| Difference in favor of railway in the mere items of transportation, - - - | | | 35 |
| To this difference may be added the following items, which indirectly operate favorably to the trade by the railway: | | | |
| 1. The use of the Pottsville landings not required, - - - - | 12 | | |
| 2. The lateral road cars and boats not required, saving in capital, etc., equal per ton, - - - - - | 10 | | |
| 3. The use of less capital required to trade on the railway, which will be enabled to give the operator a fortnight credit on the toll and freight of $1 50 per ton, leaving only the *first cost of coal at the mine*, say $1 per ton for white ash, to be provided, which, with the freight at least on the canal, say $2, must be *cash*, saving, - | 6 | | |
| 4. Gain, in being able to turn *one dollar* on the railway *three* times, while the *two dollars* on the canal can be turned only *once*. These two last items of vital importance in reference to money facilities hereafter, - - - - | 15 | | |
| 5. Saving by the avoidance of any *heavy dead* stocks in winter, comparatively, and an uninterrupted employment of capital during the whole year, equal to per ton, | 12 | | |
| 6. Difference in favor of Broad street as a depot for *retail at Philadelphia*, over the wharves on the Schuylkill, a horse being able to deliver 15 tons per day from Broad street to 5 from the Schuylkill, - | 20 | | |
| Amount carried over, - - - | | 75 | 35 |

| | | |
|---|---|---|
| Amount brought over, - - - | 75 | 35 |
| 7. Time saved by shooting from the cars, loaded at the mine, into vessels or barges on the Delaware, being as 3 to 1 compared to the *tedious process* of loading by the wheelbarrow, as on the Schuylkill, - | 10 | |
| 8. Difference in value of coal consigned to New York in *barges* over that by the only mode of shipping by vessels on the Schuylkill; in the former it can be ready screened for delivery at once from the barge to the consumer, and in steam barges with the power of locomotion in themselves, the difference will be still greater, and although 25 cents has often been paid, say, per ton, - - - - | 15 | |
| | 1 00 | |
| Total difference in favor of the trade by the railway, - - - - | | $1 35 |
| Deduct present toll on the canal, - - | | 54 |
| Difference in favor of the railway *over and above* any toll on the canal, - - | | 81 |

In thus reducing these indirect items in favor of the railway to figures, it is not pretended that it can be done very accurately, but that *they exist and sufficiently* to give the railway the command of all the trade it can accommodate, can hardly be denied. The ability of the road to deliver, as a *business load*, 150 to 200 tons by one engine of *the lighter kind*, and that without any waste of coal, at first so stoutly denied by its opponents, is now fully established, and with these are its claims to cheaper transportation than by canal, equally established. So again, as time is given to the road to develope itself, will it also be discovered that the indirect items just enumerated in its favor are more or less well founded; and the canal will not be able to contend against the railway, except under an arrangement, by which the latter shall put its rate at a level that will allow the boatmen to earn about $1 per ton, and the canal to maintain a toll of 50 cents per ton. This level by railway is between $1 75 to $2 per ton, and then by both avenues will it be practicable to maintain a preponderance of the trade in the Schuylkill valley, and still afford the coal to the consumer at a rate

lower than has yet obtained, and be a wholesome check on the competition from other regions, while a steady and moderate rate of price will be maintained all round.

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[From the Civil Engineer and Architect's Journal.]

MR. VIGNOLES'S LECTURES ON CIVIL ENGINEERING, AT THE LONDON UNIVERSITY COLLEGE.—ON ARTIFICIAL FOUNDATIONS.

LECTURE I.—*November* 25, 1841.—After offering some comments on engineering generally, the lecturer alluded in particular to that important portion where the skill of the engineer was most required—viz. foundations. After some instructive remarks upon the subject, he said that for the foundation of bridges a network of timber had been used, and was found to be very good so long as it was under water; but if it were liable to become dry, and exposed to the effects of the atmosphere, it was sure to fail. He recommended concrete as far superior to timber; he had seen concrete forced into a quicksand, and no weight could afterwards force it out. Brick, earth and clay form excellent foundations—the whole of St. Paul's, except the northeast corner, was built upon such a foundation, of from four to five feet thick; at the northeast corner, the architect being afraid to trust to the ground, it being rather softer than the other parts, had the clay removed, and a well of from twenty to thirty feet square sunk to a depth of about forty feet, where the hard bed was found; he then raised a solid mass of masonry to within nine or ten feet of the surface—arches were turned, and the foundation finished at an enormous expense; whereas, a few cubic yards of concrete would have answered equally well, if not better. All must have noticed the hole that was filled up in laying the concrete foundation of the Royal Exchange; there a few cubic yards of concrete did the work more expeditiously, and as well as the ingenuity of the mason could have effected it; he alluded to some of the most remarkable instances of the prodigality of architects in laying foundations, as the Barriere de l'Etoile (a trumphal arch at Paris,) where the cost of the foundation far exceeded the amount of surface work; and the viaduct of the Valley Flore, in which a mass of solid masonry, thirty feet thick, was erected, extending all across the valley. In these cases concrete would have answered the purpose equally well, and at an enormous reduction in expense Mr. Vignoles stated that the leading principles he wished to impress upon the minds of the students were—extension of base and equality of surface. He then, at some length, explained the different foundations that had been used for bridge building, and mentioned particularly Ranger's patent for curing defects where foundations have given way—viz. by using hot water to concrete applied in boxes, the hot water causing the concrete to expand. This was applied to the foundation of the custom house when it had given way in consequence of a failure in the piling, which rendered necessary the application of an artificial for a natural foundation. He then remarked upon the various

methods now in vogue for keeping the piles of bridges dry while under repair, alluding to caissons, and Mr. Tierney Clark's method of putting in the foundation of the landing place at Gravesend by portable coffer-dams. The professor concluded his instructive lecture, stating his wish to popularise the knowledge of engineering as a means of benefitting the public at large.

Lecture II.—*Wednesday, December* 1, 1841.—In the first lecture Mr. Vignoles gave the general principles of the various descriptions of foundations; in the present, he proceeded to illustrate those principles by diagrams. He stated, that if a good foundation were provided by nature, the subsequent operations were simple, the main point being to imitate nature as closely as possible. Where the soil was bad, considerable skill was required; for instance, in laying the foundation for the pier of a bridge, a wall, or a column, the first point was to give the base extensibility, in proportion as the natural soil was weak, so in equal proportion must the size of the base be increased—the pressure must also be equal; the soundness of the foundation not depending so much upon the amount of settlement as upon its equality. There were various ways of obtaining this—viz. by the use of concrete alone, or in conjunction with timber, timber alone, or stone, or brick. Having so much insisted upon the necessity of an uniformity, it must be supposed that no portion of the artificial soil should escape; where that was likely, *sheet piling* must be restored to. He then, by means of diagrams, explained the nature of that method—it being by driving piles close together, all round the foundation; the piles being (say) four inches thick, and as long as might be necessary. This method entirely prevented the escape of the soil in any manner but in a vertical direction, and ensured an uniform sinking, however bad the natural soil might have been. He then alluded to a very large chimney, twenty-two feet square, where the natural soil was a shifting quicksand; concrete was put in in layers, until the bed was eight feet thick; on this was placed a layer of flag-stone, five feet square; eight days after the work was completed, the whole sunk eighteen inches, without the least deviation from the perpendicular. Other modes had been adopted, among which was the following:—A number of timber balks were laid across, and concrete placed in the spaces between; then filled up with bricks; timbers were laid in a cross direction, and the flat stones placed upon them. In this instance the wood was laid where no change of atmosphere could effect it. The nature and use of a coffer-dam was then explained, and the professor, at some length, showed the danger of incautiously drawing the piles; the vacuity occasioned by their withdrawal being filled up by the surrounding matter, greatly injured the stability of the foundation. In making one of the London bridges, a great disfigurement had occurred in consequence of the incautious withdrawal of the piles, one side of the pier having sunk one foot. The modern plan to prevent such accidents was to have a double coffer-dam—the piles of the inner one being cut off, and the outer piles might be withdrawn without danger. In laying foundations,

he supposed there was a layer of soft ground, of moderate depth, with a hard substrata; piles must be driven through the soft soil into the hard bed; a very slight depth would be sufficient, but still, in most cases, sheet piling would be necessary.

The professor said that he was lately indebted to an officer of the Bengal Engineers for an account of a very ingenious method, almost universally practised in laying the foundations of bridges and temples in India. It would not answer here, labor being so dear; but there, where wood was very scarce, building materials in great plenty, and labor very cheap, it was the simplest and most effective that could be imagined. From the explanation, it appeared that the system was the same as piling, but instead of using wood, small wells of brick work were substituted. Take, for instance, the pier of a bridge,—a small well of brick work was constructed —say, six feet deep, seven feet in diameter, with a hole through it, three and a half feet in diameter; this is placed on the sandy bed where the foundation is to be made; a workman gets into it, and undermines the well from the inside, the earth being drawn up in buckets, additional layers are added to the top of the well until a sound bottom was reached; and the singularity was, that there was not one or two of these little wells, but hundreds, and in certain cases, to a depth of fifty-five feet; arches were then thrown across, and the superstructure raised. When the foundation was in the bed of a river, the excavation went on by the workmen driving through the water to the bottom of the well, and working there until obliged to come to the surface for air; for instance, through ten feet of water in the river and to the extent of forty feet of water in the well—one of the most extraordinary instances of perseverance upon record. English engineers had somewhat abridged the labor by substituting an oblong square of fifteen feet by four feet, with two elliptical holes for the workmen, so that, instead of three wells of six feet, they get one of fifteen feet—the principle being precisely the same.

In France a number of bridges had been built where the water was not rapid, upon a very simple foundation; a framework of timber being made, furnished with short piles at the corner, and laid in the bed of the river, and the superstructure raised upon it by means of a wooden diving-bell. The *pier perdue* was another way, but could only be used in still water; a quantity of stones were thrown in until a foundation was obtained; where there was any current this foundation was sure to give way, as in Plymouth breakwater and Kingston harbor. He then alluded to the case of one of the London docks, where the wall being made with too great a curve, from the want of pile sheeting, the soil gave way—the engineer adding fresh matter until the toe of the wall actually appeared (to the astonishment of all) above the surface on the other side. He then gave examples of several original methods of preparing for the formation of foundations in Italy and Ireland by means of baskets of stones, etc.

*Concrete.*—The professor next explained the nature of concrete, and gave directions for its formation,—viz, one part of lime, twice

that quantity of sand, and twice as much broken stone or gravel as there was sand.

The goodness of the concrete depended upon the quality of the lime. In making concrete, it must be borne in mind that the materials were far more bulky separate than when mixed; for instance, to make a cubic yard of concrete, which contained twenty-seven cubic feet, it would be necessary to have thirty-four cubic feet of materials, besides the water. The three ingredients should be mixed dry, and the water added; in slaking, the concrete will expand about one-thirtieth in bulk.

The great expense of coffer-dams, and of piers generally, had lately led to a very peculiar construction of bridges by piling only, as, for instance, in iron bridges no masonry being used. The professor stated that he had built seven or eight bridges upon that system; the piles were driven in and the iron work erected upon the wood. It had been tried to substitute cast iron for piles instead of wood, but they had not succeeded, the iron being very liable to break. He also alluded to a beautiful arrangement for fixing branches to piles by means of a sliding collar, but which is impossible to explain without diagrams. A French work, above 200 years old, was produced, with some very curious engravings of the modes then in use for securing foundations, and which proved that we are using the same means at present, and that many of our so-called new processes were in use at that time. He then concluded by stating, that, at his next lecture, he should bring forward some more general rules respecting foundations, and after that proceed to consider the best method of securing slopes of earth now so generally in use.

Lecture III.—*Wednesday, December* 8, 1841.—Mr. Vignoles explained that at his former lecture he had applied the term "concrete" too generally, and would now explain the difference between "*beton*" and "concrete." Beton was formed of the usual quantity of sand and gravel, broken stones, etc., but, instead of using the ordinary stone lime, hydraulic lime was applied. He then stated that beton is used exclusively under water, concrete only where water does not get in: beton never sets until it is under water, while concrete will not set except it is dry. The lime used for beton must be first slacked, while for concrete it slakes in the process of mixing. Beton sets best when let down gently in cases, and concrete when scattered from an eminence. Beton takes months to become hard, while concrete hardens in a few minutes. They both are in purport essentially the same,—to form an artificial stone or rock,—the one for works under water, and the other for those on land. He then alluded to the knowledge of the ancients of beton and concrete, and read extracts from the works of sundry authors, from Josephus to the present time, proving that assertion. The use of piles was also very ancient, the foundation of a brick pyramid in Egypt having been constructed on that principle. After impressing upon the minds of the students the great importance of a good foundation, and the efficacy of concrete for attaining that end, he concluded, by stating that his next lecture would be again

on the subject of foundations, and after that he would proceed to lecture upon slopes of earth, and explain the causes of the late accidents upon the different railways, pointing out where the errors of judgment had occurred.

LECTURE IV.—*Wednesday, December* 15, 1841.—Mr. Vignoles commenced by explaining the mode in which piles were driven in, and produced a model of a pile-driving machine (from the museum of the college,) by means of which he showed the method in which steam power was applied to that machine for expediting the work, stating, however, that, far from that application being a novelty, he had used it himself twelve or fourteen years ago.

*Rock foundations.*—Having treated in his former lectures upon foundations in natural soils, or various kinds of artificial bases, he would now notice such as were of the composite order, being partly on rock and partly requiring artificial means to render them sufficiently sound for the required purpose. It often happens that, in making a bridge, there may be rock on both sides of the river, and the first pier may rest upon rock, while the second and third may have an insecure foundation, in consequence of a "pot-hole" (as it is called) of sand unexpectedly being discovered in the very spot where these piers are to be erected; the only plan to get over this difficulty is to cut the edge of the hole in steps; sheet pile it a short space from the wall of the hole, and fill up the intervening space between the piling and the hole with beton or some other substance, and thus form a continuation of the rock itself. Difficulties also present themselves in solid rock foundations; for instance, in such an erection as that at the Devil's bridge; the ravine over which the bridge is to be thrown may have been formed by the running of water,—the strata, accordingly, runs with the usual inclination on both sides. If foundations for the piers of the bridge were not sunk deep enough into the rock, the press of the water filtering through the fissures of the strata have such force that, notwithstanding the resistance of the arch, he had known instances of the pier being actually pushed outwards. The only method of avoiding this was to sink the pier so low into the rocks, and, by means of steps, secure it so firmly, that the force of the water must *break* the pier,—not force it outwards,—before it could destroy the bridge. The professor, before going into the question of rock foundations, begged to state, that in these lectures he only laid down the general principles of foundations; he could not go into the details of the business, and the circumstances of stone foundations were so varied, that it was only by a life of labor and experience that the best method could be arrived at; he wished that each student should, in his private study, well consider, and by reading, test the correctness of the principles which he had laid down for their guidance. A whole year's lecture, repeated every day, would be no more than sufficient to draw the attention of the student to important points—the details could only be gained by practical experience. In preparing the foundation of lighthouses, the whole resources of the engineer must be called into action. A

lighthouse must be built in such a manner that it must actually grow from the rock; there are instances where lighthouses have fallen in a body. He could mention one in Ireland, the foundation of which was a solid rock; he saw a party who witnessed its fall, and who informed him that it fell in a solid mass, tearing away a portion of the rock with it. The fault was, that the foundation was not sunk deep enough into the rock. He then alluded to the celebrated Pharos (of Pharos) of Alexander, which was justly reckoned one of the seven wonders of the world; it was built about 283 years B. C., and received its name from the island on which it was built; it was 550 feet high, and the base was 150 feet square, and could be seen at a distance of 40 English miles, Josephus, and many other authors, had given descriptions of it, which pretty well agreed; and what was most extraordinary, that the very same method of making the foundation was practised then as now. The stones were dove-tailed together, dowelled, and run with lead, so as to firmly secure them in their places. The cost of the building amounted to no less a sum than £200,000 of our money, and it lasted above 16 centuries; no diminuation in its height occurred until after a 1000 years from its erection, at which time about one-third of its height was wasted away by time, and it was only within about 400 years that the whole is supposed to have been destroyed, and that only by means of an earthquake. He then remarked, that it was very seldom that the name of an engineer was handed down for 2000 years, but all accounts agreed that Sosastros was the name of the engineer who erected this wonder of the world. The celebrated Corduan, or, as it is generally called, Cordovan lighthouse, at the mouth of the Garron, is built upon the same principles as the Pharos; this lighthouse is, however circular, but the masonry is not calculated for durability, it being built of freestone. The expense of this lighthouse was enormous, as must be supposed, when millions of francs were expended upon ornament, which was the more absurd, when it was considered that it stood upon a barren rock, in the middle of the sea. He could not help quoting a line of Pope—

"'Tis only usefulness that sanctifies expense."

This is a sentiment that he wished to impress upon the minds of all his students, for it was a great fault of modern engineers to expend great sums upon ornament, which could be far better employed upon actual necessaries. He then turned to the Eddystone lighthouse, and related the histories and fates of the two lighthouses preceeding the one now standing, which was erected by the genius of Smeaton, and strongly recommended his pupils to read the account published of that great work. The Eddystone rock is peculiarly interesting to the engineer; it is found first at about one mile deep in the ocean, and then rise gradually about one foot in ten, until it reaches near the level of the sea, when a sudden crop makes its appearance, and rises above surface. From the peculiar formation of this rock, there is always a heavy run upon it, which renders it so very dangerous. The learned professor, after explaining at some length the process of the erection of this celebrated lighthouse, concluded his lecture.

LECTURE V.—*Wednesday, December* 22, 1841.—*On earthwork.*—The professor commenced by stating that earthwork, taken in the present extended sense of the word was but little known to the ancients. The gigantic operations in earthwork of modern times correspond with the viaducts of the ancients. Our earthwork may be confined to excavation, cutting and embankment, or getting and filling, as ordinarily denominated by contractors. He then went through the whole process, giving the scientific and common names of each description of work. With respect to the works of the ancients, in the canal made by Cyrus, the Phœnicians were the only workmen who cut the canal with slopes—all the rest employed, cut straight down, and in consequence, the former stood, while the latter fell in. The river Po, in Italy, was a curious instance of embankment; this river is situated in a very flat country, and makes an annual deposit of a calcareous matter, which hardening, raises the bed of the river in a slight degree every year. The ancient inhabitants, to prevent their country from being inundated, were obliged to raise a small embankment on each side of the river—perhaps two or three feet high—which, having served for some years the desired purpose, and the bed of the river having become higher from the deposit, the embankments required to have still more added to them, until, after the lapse of centuries, the bed of the river, from the constant deposit of calcareous matter, and the consequent necessary additions to the embankments, to the height of thirty feet, is now several feet above the level of the surrounding country. This work looks like one of our modern gigantic works, but it bears no comparison to the labors of the present day, it being but a work performed from year to year, in small portions at a time, while ours have been formed at one operation. From all his researches, he, therefore, came to this conclusion, that, until late years, earthwork was but little known; he could make the same remark with respect to cutting. This work was first treated systématically by military engineers in fortifications on the continent after the invention of cannon; authors of that period lay down many curious rules for forming ramparts. Various useful calculations are given to determine the best mode of making the matter taken from the ditch exactly sufficient to form the rampart, in order that there should be none either to procure or carry away, the next is in the construction of canals; the same rules were followed as in the construction of ramparts. In road making the same calculations were made; the whole aim of the engineer being to make the imaginary line, called the "balancing line," so perfect, that the earth removed from the eminences should fill up the hollows in the irregularities of the country through which the road was to be made. The cause of these fine calculations was the difficulty and expense of carrying away the superfluous earth to another place. The absence of great undertakings on the continent is attributable to the want of our modern appliances to get rid of the superabundant matter. In the contracts sent in by foreigners for works abroad, it is amusing to see the finical exactness with which the contractors calculate the expense of removing the first 100 yards, then the next 25 yards,

and so on increasing until they get to 300 yards, beyond which the price is enormous. It is only within the last 3 years that they seemed to have the slightest idea of the plans in use in England for facilitating this work; it is certainly not more than 30 years ago that we commenced using the tramroad. First of all, the only plan was to remove the earth in barrows, then the clumsy three-wheel cart was introduced, after that tramroads, and now edge rails, with the application of a locomotive, so that 30 years has changed the load from $2\frac{1}{2}$ cubic yards to nearly 100.

Before railroads came into general use, deep cuttings were executed, and one remarkable instance Telford has left behind him in the Birmingham canal, which is remarkable for boldness of idea and success of execution. Near Market Draton there is an embankment, begun 15 or 16 years ago, and which is as yet hardly finished, so great has been the slipping and so difficult the remedy. This work is a remarkable instance of combined bad effects of a bad mixture; the slopes have flatted down until nearly in the proportion of 14 to 1, and it is now more like a large hill than an embankment. There is an instance of a deep cutting, by Dodd, at the Highgate archway; it was intended, first of all, to make a tunnel, but from the constant slipping of the earth, it was obliged to be made into an open cutting. The present bold mode of cutting down large hills and filling up deep valleys, in the formation of railways, is due to George Stephenson, and in the construction of large cuttings and embankments for canals to Telford, while Dodd made the largest cuttings for roads. On the Holyhead road the failure of the embankments and cuttings in the London clay will teach a good lesson to the young students. The point to be considered is, which, of masonry, aqueducts, tunnelling, embankments or cuttings, would be the cheapest mode of doing the work proposed. At the present time, earthwork is the cheapest, for modern practice has reduced it to a price per cubic yard. In the contracts for the Paris and Rouen railway, the contracts sent in by the French engineers were invariably three or four times the amount of those sent in by English contractors—thus, notwithstanding the expense of transporting the workmen into France, the whole of that work is in the hands of Englishmen.

The engineer, to form a just calculation, must well study the character and mechanical properties of the soil and the necessary slopes. Experience alone can teach these points. There are many varieties of the London clay, which, when cut down to a certain depth, on exposure to the atmosphere, are sure to slip; another cause is the great haste with which the embankments, etc., are formed. When the water does not penetrate, this clay is very hard, but after exposure it melts away like tallow, and the only remedy is to get rid of the water by draining. When a slip takes place, the toe of the embankment bulges forward; in the first instance, the surface should be well drained a short distance from the edge—the drain to be puddled, in order that the water should not penetrate; borings should be made horizontally and the water tapped; when expense and time are no objects, the whole should be cut in steps,

and drained by means of wattles, so that, if a slip takes place, it is only partial. The force with which the toe of the embankment bulges out is such that a wall of masonry would be of no use, as it would be pushed out; the most effectual preventive or remedy, is wattling and bush drains. When time will allow, it is better to make the embankments in layers, and between each layer of earth putting in a course of brushwood, clippings of hedges or wattlings. When embankments are obliged to be poured out hastily, allow them to take their natural slope, and if it slips let it remain, for however much it may be attempted to reduce it to its former shape, it will again slip and regain its position. A good practice to provide against slips is to form a slight abutment of earth, a short distance from the toe of the slope, so that it should stay the slip if it takes place; this plan is more particularly available when the work is obliged to be erected on a natural slope—for instance, on the side of a hill. The professor then, for the information of the younger students, explained, by diagrams, the nature of slopes, and the meaning of the expression "two feet to one," etc., and concluded by recommending that, in forming slopes, the engineer should run some risk of slips, in order to save the great expense of removing more earth than is actually necessary—the cost of repairing these slips being but little in comparison. He likened the work to an insurance on life—the risk to be run being calculated upon by precedents. The principle is to get the greatest extent of work finished at the least possible expense, and many of the great slips that have taken place might have been prevented or speedily cured, had the plans he laid down been better followed.

Lecture VI.—*Wednesday, December* 29, 1841.—Professor Vignoles stated that, before continuing the subject of earthworks, he wished to set right an erroneous impression with the public, in consequence of an expression he made use of at his last lecture; he had then recommended that "the engineer should run some risk of slips, in order to save the great expense of removing more earth than was actually necessary—the cost of repairing those slips being but trifling in comparison." He need not say that he so expressed himself, but it was always on the supposition that no risk was to be run where there was the remotest probability of danger. He mentioned this because of the circumstance of the slip on the Great Western railway, which was attended with such fatal results, and happening only a few hours after he had made that statement. From all that had been stated, it appeared that the slip itself was but very inconsiderable; the cutting where it took place was 57 feet deep, the slope two to one, and the width of the road 40 feet; the slip took place about half way up the bank. A number of smaller slips had occurred, and tiles were used for draining instead of bushes, etc., to cure them—still the mode of curing them was the same as he advocated—by drainings. As he had before stated, the slip itself was very inconsiderable, but by having nothing to check it, the earth fell upon the rails. A doubt seemed to exist whether the concussion produced in the air by the passing of the

former train had not brought it down, for the accident happened in the interval between the passing of the two trains—the first one having proceed uninjured, while the latter was attended with such fatal consequences. If the precaution had been taken when it was first observed that a slip was likely to occur, to put up a fence of hurdles to check its advance to the rails, doubtless the accident would not have happened. The manner of the slip showed that it was caused by the infiltration of water, probably a considerable way back from the edge of the cutting, or perhaps the water had found its way in by the ditch along the top; the water which had thus got into the soil having expanded during the frost, the sudden change of the weather brough down the earth. The professor then, by means of a diagram, explained the nature of the cutting, from which it appeared that the "top lift" was deposited in spoil bank; at the top of the cutting a drain had also been cut, but he was of opinion that such drains were injurious when the soil was at all precarious. The spoil bank was not the occasion of the slip, since it did not take place at the top, but bulged out in the middle. Although this slip was very small, from the fatal effects which attended it, it was the more necessary to guard against the recurrence of the like; there was but a few feet of earth on the rails, yet the effect was the same as if so many planks had been placed upon them. The Croyden slip arose from the same cause, but, though so much larger, no accident occurred. In the late accident there were but thirty or forty wagon loads of earth, and all was right again in a few hours, while in the Croyden slip 3,000 or 4,000 cubic yards of earth fell; the soil in both instances consisted of the London clay, with pot-holes of sand. It was clear that the accident was not to be set down as one of cutting, similar slips having taken place upon cuttings not more than twelve or fourteen feet deep. He must impress upon the minds of the students that it was not the length or the depth of the cutting which regulated the slopes, but the soil and practicability of drainage; unfortunately it was impossible to know exactly how these matters might stand, experience alone could teach them. He had dwelt long upon this subject, but he wished it to be understood that it was well-judged economy he advocated, not such as would, in the least degree, tend to produce such fatal effects as in the case previously alluded to.

The balancing of the line was equally necessary for railroads as for canals or common roads; it should be the engineer's aim that the quantity of the earth from the cuttings should be as near as possible sufficient for the embankments; compared with former times, the mode of transit was so much facilitated, that where some years back it was necessary that the balance line should be limited to the hill to be cut through, and the valley to be filled up, now the line might extend two or three miles. It was essential in balancing that the engineer should be aware of the different degrees of compressibility of the matter; it was known of sand that it would occupy the same cubic contents in the embankment as it did in the hill, and 1 yard or 100 yards of gravel would be still the same, but in clays it was very different, they occupying less space in the em-

bankment than they did in the hill, in their original position; 100 yards of clay would not make 100 yards of embankment, the average amount of compressibility being not less than 10 per cent., or even, upon occasions, as much as 15 per cent. He had known occasions when 100 yards cut from a hill had only made 85 yards of embankment, but, upon an average, it would require 110 yards of clay to make 100 yards of embankment. Rock cuttings, on the contrary, expanded, because the solid rock could never again be restored to the same degree of density; the difference would vary much, according to the size of the fragments, but where the pieces were large, 100 yards would make 120 yards of embankments. Chalk, again, would be rather upon the excess, though much depended upon its quality. In rock cuttings you might make them nearly perpendicular, but in chalk much discussion has arisen as to what was the proper slope, some engineers having even recommended that it should overhang the road, but he contended that it should slope, to carry off the water; he had found a slope of one quarter to one generally sufficient. Rock chalk would stand perpendicular, while several of the softer descriptions would require a slope of one-half to one, or two to one.

The professor then proceeded to speak of the correct mode of computing the quantity of earth in a cutting or embankment, and made a section of a hill half a mile long, to be cut down, the true cubic contents of a portion of which was 332,000 cubic yards, computed according to the prismoidal formula; but the ordinary method by which contractors would calculate the contents of the hill, by mean heights, would only show 310,000 cubic yards—that is to say, there would be a difference of 22,000 cubic yards against the contractor, the consequence of which had been, that the person contracting to cut down such a hill, at so much per yard, would lose, from his bad method of calculation, above £1,000. Another method was also in use—calculating by the mean area; which system, instead of 332,000 cubic yards, would show 376,000 cubic yards, being an excess in favor of the contractor of 44,000 cubic yards. Many contractors had realised large fortunes by mean areas, and sustained serious losses by mean heights. Having thus shown the erroneous methods of calculation in use, he then, at some length, explained the prismoidal formula, accompanying his instructions with many diagrams, without which any attempt at explanation on our part would be useless. The learned professor concluded his lecture by strongly recommending a close study of mathematics to the junior (all) students, as the greatest assistant to the labors of the civil engineer.

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[From the New York Tribune.]

MR. LYELL'S FIFTH LECTURE ON GEOLOGY.—ORIGIN OF COAL.

In speaking of the different strata of which the earth's crust is composed—those at least which contain organic remains—I spoke of them as so many volumes of history—as so many monuments of the ancient states of the globe; and of their different structures as

being so many leaves of these volumes. All that I can do in this short course of lectures is to take down at random, first one and then another of these volumes and endeavor not to give you any idea of the contents of the whole, but just to express something of the method employed in the attempt to decypher these ancient memorials of the earth's history. Now the volume which I intend to take down to-night is that which we term the *coal formation*; and I shall speak of it only so far as to show the relative position, and the state of the different periods when they were deposited beneath the water.

Now when I term this formation *coal*, I merely mean this assemblage of strata which rests on the older sandstone, and in which is found that invaluable fuel we call coal; and although the quantity in which it is contained is very small in comparison with the bulk and volume of the other strata, there is still great interest and importance attached to it. We see that in going from the highest to the lowest beds yet discovered the coal occupies quite an ancient position—one indicating a formation low down in the sea—as we have above it the most modern formations. We have first the post-pliocene, then the tertiary formation, then the chalk, which is made up of calcarious, matter formed mostly, at least in Europe, from decomposed shells and coals and of those green marls which are found in New Jersey, and are of such extensive use in agriculture; then we have the jura limestone or oolite, in which also are masses of coral like the common coral reefs: below this are two other groups, of which I shall not speak at present, and lastly we come down to the carboniferous or coal-bearing stratum which rests upon the thick sandstone beds, or the limestone containing corals and which like every other formation contains species of animals, shells and plants of different species, from these immediately antecedent or following. Below this again, we see limestone and shale, which enter most largely into the structure of the rocks of the State of New York and which abound in fossils.

Now a great change must have been experienced before the coal period, when the fossils were deposited. I am indebted to Mr. Sopwith, an eminent civil engineer, for copies of some models prepared by him of those sections, which are faithful and accurate representations of actual localities, as has been fully verified by Dr. Buckland and myself in examinations which we made last spring. The different strata of sand stone, shale and conglomerate, of which the carboniferous formation is composed, are here represented. The sections represent facts ascertained in cutting perpendicularly through the Newcastle coal district. They are not hypothetical, but are founded upon exact measurement. In one of these sections you see the dip of the beds is at an angle of 20°, while the slope of the valley is 40°. In the other, the dip is 50°, and the slope of the valley in the same direction is 20°. In these two cases, therefore, the relation of the slope of the valley and the dip of the beds is reversed. In both cases, also, the slope of the valley and dip of the beds are to the south. To those who are not acquainted with these technical terms, I may say, that the deviation from a horizontal plane

of the beds is called the *dip;* while the *strike*, as it is called, is the extension of the strata in a direction at right angles to the dip. In this case, as the dip is to the south, the strike must be from east to west. The flexures of the valleys depend on their inclination relatively to the dip: and these two sections cut through beds of coal and shale and sandstone—the shale being indurated clay—are illustrations of cases in which the two strata come up the surface according to the various relations of the slope of the valley and the dip of the bed. It is a rule among miners that when the dip of the beds is less steep than the slope of the valley in the same direction, then the V's as they are termed, with point upwards, those formed by newer beds appearing in a superior position and extending higher up the valley. But when the case is reversed, and the dip of the beds is steeper than the slope of the valley, then the V's point downwards and those formed of the older beds appear uppermost. These rules may often be of great practical service in many cases. For example, suppose a miner first to begin his operations in one valley with the structure of which he is familiar. If he should sink his shaft through the formation above, he would come to the coal which is below. But suppose one unacquainted with these rules which I have been explaining to go to another valley; and in England he might easily go to such a valley, for these cases, as I said, are not hypothetical. He might, continuing along the same side of the hills as he had seen in the other valleys, where he observed the same *out-cropping*, as it is termed, of the coal seams, suppose, reasoning from his former experience, that he might begin his workings in the bed at the higher part of the valley with the expectation of coming down to the other bed. But he would be disappointed, as you will readily see, by observing that the uppermost bed is the lowest down in the valley, and the lower bed is the highest up. This you can easily trace with your eye upon the sections. An acquaintance with these rules and their application is of the greatest importance to those speculating in mining transactions. In the coal field of Pennsylvania, to which I shall presently allude, near Pottsville, I saw an exemplification this year of the two cases alluded to —when in the coal of the same valleys the V's in some cases pointed one way, and in the others in the opposite—the dip and slope being both towards the south. There is nothing more singular or which has struck me so forcibly in respect to the coal fields of this country, as their close resemblance to those of the north of Europe, and of England in particular. I have travelled on the north side of the Alps towards the south, and have been astonished to find minerals of fossil of entirely distinct genera from those met with in the Pyrenees. Nor have the chains of mountains any thing to do with this remarkable change—for the beds were formed at the bottom of the sea before the mountains existed. Observing this great change, then, in the short passage of a few hundred miles, it seems to me not surprising, that in passing at the distance of three or four thousand miles, from England to the Apalachian chain in Virginia, we should find the coal measures the same as those we left behind, represented in the red sandstone, and containing white grit and slaty

shales, and clays not slaty, and beds of conglomerate containing quartz pebbles.

It is generally admitted by geologists that *all that fuel which we call coal is of vegetable origin.* If there has been any dispute with regard to this, it was settled when a portion of the Newcastle coal some years ago was submitted to a microscopic examination. After cutting off a slice so thin that it should transmit light, it was found that, in many parts of the pure and solid coal in which geologists had no suspicion that they should be able to detect any vegetable structure, not only were the annular rings of the growth of several kinds of trees beautifully distinct, but even the medullary rays, and, what is still more remarkable, in some cases even the spiral vessels could be discerned. But besides these proofs from observing a vegetable structure in the coal itself, there has been found in the shales accompanying it, fern leaves and branches as well as other plants, and when we find the trunks of trees and the bark converted into this same kind of coal as we find in the great solid beds, no one will dispute the strong evidence in favor of the vegetable origin of this coal. If we find a circumference of bark surrounding a cylindrical mass of sand, we know that it has been a hollow tree filled up with sand, nor can there be any doubt that the coal is formed of vegetable matter. No less than three hundred species of plants have been well determined by botanists, some of whom have devoted a great part of their lives to this study. From this it is to be inferred that the carboniferous formation of Europe and America is made up of comparatively recent plants. I will allude to three or four of the most peculiar facts that lead to this conclusion.

In the first place the boughs and leaves of ferns are the most frequently and strikingly met in America as well as in Europe. So perfectly have they been preserved that there can be no doubt that they are really ferns; and in some cases even their inflorescence has been preserved at the back of the leaves. Where we have not the flowers and prints remaining, we have found it possible to distinguish the different species of fossils and ancient ferns by attending to the veining of the leaves. At least one hundred species are determined in this way. The most numerous of these vegetable veinings are those which have been called *Sagillaria*, or tree ferns. Their stems are found to be fluted vertically, and in the flutings are little stars, as it were, each of which indicates the place where the leaf was attached; and it is evident, as M. Adolphe Brongniart has shown, that they are recent tree ferns. One argument for believing this is that, although the bark of these trees is so well marked that forty-two species have been described, yet there is never found any leaf attached; while we have in the same beds loose leaves in abundance which have no trunks. The natural inference is that they must have belonged to the aborescent ferns; as for instance, the section *Cauloptoris* is admitted by all to have belonged to this species. The fact is also important because the tree ferns and especially the *Cauloptoris* are now known to be exclusively the inhabitants of a warm and humid climate;—much more hot and moist than in those parts of the globe where coal now

abounds. For we find coal not only in England and Nova Scotia, but as far north as Melville's island and Baffin's bay, in a climate where the growth of such fern plants is dwarfish and stinted. It is evident that when these vegetables existed there must have been a warmer and probably a more equable climate than now even in warmer latitudes.

[To be concluded in our next.]

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Academy of Sciences.—*Sitting of February* 21.—A letter was read from the Academy of Sciences and manufacturers at Lille, requesting the Academy to support an application to Government against the suppression of the beet-root sugar manufactories. M. Arago, the perpetual secretary, recommended that the Academy should not comply with this request, since it was of a political nature, and his advice was adopted. Some curious experiments were mentioned as having been lately made by Captain Bailly, of the engineers, on an Artesian well at Lille, which had exhibited some remarkable phenomena of intermission in the discharge of the water. M. Bailly had proved that these intermissions corresponded with the tides of Dunkirk. A commission was named to report on the subject. M. Arago read a communication from Mr. Nasmyth, an English engineer, that it had been observed on several lines of railroads in England that the rails never rusted when they were traversed by wagons going always in the same direction; but that when they served for wagons going in two directions, as in the case of a single line of rails, they became rusted very soon. M. Matteucci announced that he had succeeded in reproducing the celebrated experiment of Galvani, by putting the nerves and the muscles of a living animal in communication with each other. This instantly produced an electric current, susceptible of being multiplied by an arrangement similar to the voltaic pile; and he had thus produced deviation in a galvanemeter, amounting to 25 degrees. M. Galle, of Berlin, was stated, by M. Arago, to have observed the comet of Encke, within a short period, and had found it differ by only one minute from the place assigned.—*Paris paper*

Exportation of Machinery.—The select committee of the House of Commons, lately appointed to inquire into the operation of the existing laws affecting the exportation of machinery, have just published their second report to the House. This report is much too long to allow of any detailed reference to it, but we subjoin the final recommendation of the committee on the subject, which is to the following effect, viz.:—"That, considering that machinery is the only product of British industry upon the export of which restraints are placed, the committee recommend that the law probibiting the export of machinery should be repealed, and the trade of machine making be placed upon the same footing as other departments of British industry."